Balloon Flight Integration
Calorimeter Calibration Needs

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Calibration during integration

At convenient times during BF payload integration, we require

- Muon calibration
  - Overnight run
    - reqmt: >8 hrs
    - Goal: >12 hrs
  - CAL-only trigger or TKR trigger.
  - Data stream
    - reqmt: at least CAL-only
    - goal: full instrument
    - TKR recon for muon trajectories.
  - Need access to data files!

- Electronic calibration
  - Full "intlin" calibration
  - CAL-only data stream, CalGSE
    - No need for full instrument data stream. Full stream would complicate analysis.
  - ~3 hr acquisition time
  - Analysis of data is off line in IDL.
  - No additional analysis software burden.
  - Result is ADC_to_fC tables.

Does BF GSE support full CAL commanding? What's the cmd i/f?

How can we do these things without switching to CalGSE?

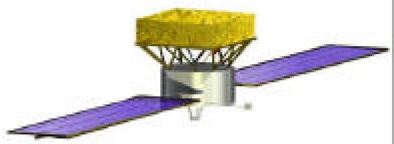
Pre-flight calibration

Prior to sealing the pressure vessel and declaring flight readiness, we require

- Muon calibration
  - Overnight run
    - reqmt: >8 hrs
    - Goal: >12 hrs (~300 good muons per cm^2)
  - CAL-only trigger or TKR trigger.
  - Data stream
    - reqmt: at least CAL-only
    - goal: full instrument
    - TKR recon for muon trajectories. Need access to data file

- One big, long muon calibration
  - Either Palestine or GSFC
  - >4 days (~2500 good muons per cm^2)
  - TKR trigger.
  - Full data stream and TKR recon.
  - Result is good map of light asymmetry.

- Electronic calibration
  - Full “intlin” calibration
  - CAL-only data stream, CalGSE
    - No need for full instrument data stream. Full stream would complicate analysis.
  - ~3 hr acquisition time
  - Analysis of data is off line in IDL.
  - No additional analysis software burden.
  - Result is ADC_to_fC tables.

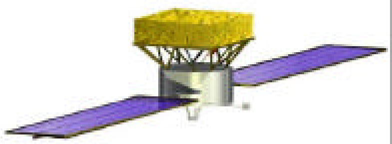


Flight-ready calibration

After declaring flight readiness, we require

- Muon aliveness test
  - Question: Are all channels still alive?
  - Short run
    - reqmt: >15 minutes?
    - Goal: As long as thermally safe inside pressure vessel.
  - Assume TKR trigger.
  - Full instrument data stream. Need access to data file.
  - Subsequent TKR recon for muon trajectories.

- Electronic monitor
  - Question: Any gross electronic changes?
  - Quick “intlin” calibration
  - ~15-minute acquisition time
  - Full instrument data stream.
  - Analysis of data is off line in IDL.
  - Need access to data file.
  - Need raw tlm read routine for IDL.
  - Output summary figures.



Balloon flight GCRs

- **GCR rates for Palestine balloon flight**
  - Require passage through uppermost full Si layer and bottom of CsI
  - Used CREME96 for 35km above Palestine in 2001, from H to Ni
  - See http://gamma.nrl.navy.mil/glast/tech_memos/cremeballoon.pdf

Assuming 8 hrs at float

~4000 CNO

~900 Ne, Mg, and Si

~250 Fe

to play with.

Species	Total rate (per hr)	Non-fragmenting rate (per hr)
C	220	63
N	58	15
O	220	55
Ne	35	8
Mg	46	10
Si	35	7
Fe	29	4

Integration issues

- Balloon flight
  - “What is needed to ensure instr works on delivery?”
    - Command interface – e.g. CalGSE
    - Data interface – e.g. CalGSE
      - Realtime displays – e.g. CalGSE
      - Off-line post processing – e.g. IDL and CAL routines
      - NRL has supplied some sample diagnostics, will provide more.
- LAT flight instrument

Integration Database

- The various calibration processes produce a number of parameters describing the response of the CsI logs.
  - All are time-dependent (TBR).
  - Time scale is likely to be ~ weeks to months (TBR).
- Calibration Parameter Database is a service of Software Central.

1. Pedestals
   - Accumulated on board
     - Telemetered: pedestal, pedestal width, diagnostic histogram
     - Optional diagnostic mode telemeters full CAL data set, i.e. not zero-suppressed.
       - 2 bytes x 2 parameters x 4 ranges x 2 ends x 1536 logs = 48 kB

2. Differential linearity correction
   - Make the CDB smooth.
     - Worth thinking about some more. Consider 1 byte per ADC bin per range.
       - 1 byte x 4096 channels x 4 ranges x 2 ends x 1536 logs = 50 MB

Calibration Parameter Database

3. Integral linearity correction (ADC to fC)
   - Electronic calibration
     - Internal charge-injection circuit; used during in-flight diagnostic mode
       - 4 bytes x 10 parameters x 4 ranges x 2 ends x 1536 logs = 480 kB
   - GCR calibration
     - Might uncover additional non-linearities. Might not; thus these might not be used.
       - 4 bytes x 5 parameters x 4 ranges x 2 ends x 1536 logs = 240 kB

4. Gain (optical conversion efficiency: fC to MeV[center of log])
   - Accounts for light collection: electrons at preamp per MeV deposited
   - Calculated from GCR Calibration data. Updates ground calibration.
       - 4 bytes x 4 ranges x 2 ends x 1536 logs = 48 kB

5. Light attenuation model (MeV[center] to MeV[position])
   - Accounts for variation of light collection along each log.
   - Calculated from GCR Calibration data. Updates ground calibration.
   - Small and large PINs have same light attenuation, so each log has 3 models:
     - Individual ends
       - 4 bytes x 5 parameters x 2 ends x 1536 logs = 60 kB
     - Sum of ends
       - 4 bytes x 5 parameters x 1536 logs = 30 kB

Eduardo asks ...

- "Inputs to in-flight calibration?"
  - I assume "in-flight" means "on-board the LAT."
  - Pedestal collection and histogramming occurs on board.
  - Electronic calibration triggering and collection occurs on board.
    - eCalib analysis is on ground.
- "Inputs to off-line calibration?"
  - Flight telemetry
    - Pedestal histograms
    - Electronic calibration triggers
    - GCR calibration triggers
  - Ground calibration results
- "Inputs to Science database?"

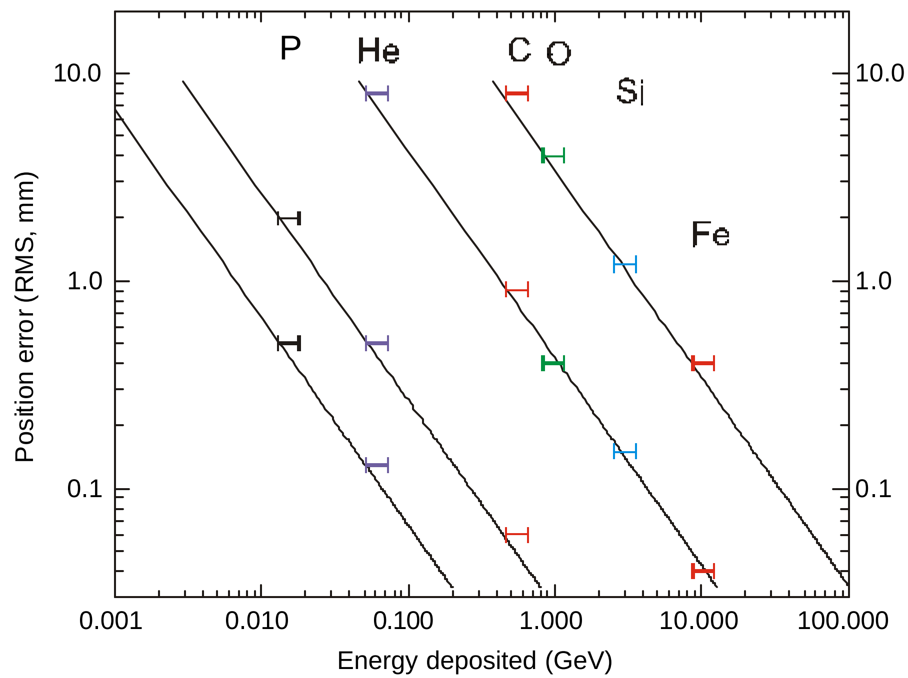
Appendix 1:
Calibration with Cosmic Rays

High flux of GCRs gives good calibration of full dynamic range.

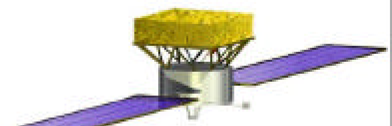
- Concept:

1. ACD flags events > few MIPs.
2. ACD flags 1 in 1000 single-MIPs.
3. Accept only events with good TKR.
4. Accept only events with no charge-changing interactions in CAL.
5. Correct ΔE for pathlength in CsI bar.
6. Accumulate dE/dx in each bar.

- Derive calibration with statistical precision of better than few % each day over full dynamic range.



He: ~140 Hz
CNO: ~10 Hz ⇒ ~1100 per xtal per day
Si: ~0.4 Hz
Fe: ~0.8 Hz ⇒ ~70 per xtal per day



Appendix 1: Calibration with Cosmic Rays

- **Questions for simulation or analytic estimation:**
  1. What is rate of >few MIPs in ACD for everything but primary GCRs? Does this trigger add significantly to data volume?
  2. How well are CsI bars on outer edge of calorimeter covered by tracked GCRs? What is the rate of each species?
  3. How does rate of useful GCRs scale with geometry cuts?
     - Cuts with CsI bars. Cuts for good TKR geometry.
  4. What is the shape of ΔE distributions for useful GCRs? How well can they be centroided?
     - Finite width from dE/dx dependence on E_0, Landau fluctuations, and pathlength uncertainty.
  5. Calibration above ~10 GeV: Use long-pathlength Fe. What is rate? How well is pathlength known?

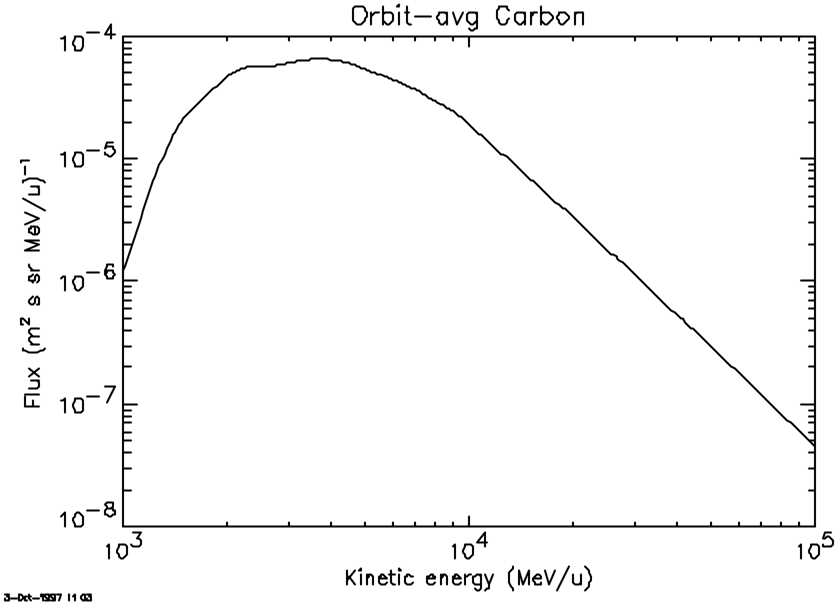
Appendix 1: Calibration with Cosmic Rays

Particle fluxes

- CREME96 for 28.5 deg orbit for abundances and spectra.
- Conservative estimates: Required GCR to pass through upper and lower faces of CAL.

Particle ranges

- At 2 GeV/n in CsI, ranges of C and Fe are 440 g/cm^2 and 110 g/cm^2, resp.
- All incident C will penetrate CAL ($9X_0$ = 76 g/cm^2).
- All but low-energy, large-angle Fe will penetrate.

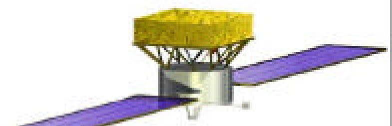


Z range	Rate (s^{-1})
1 – 28	1020
6 – 28	12.4
10 – 28	3.6
24 – 28	0.7

Appendix 1: Calibration with Cosmic Rays

- **Nuclear interactions**
  - Majority of GCRs suffer nuclear interactions as they pass through calorimeter.
  - Interaction lengths:
    - $\lambda_{N,CsI}$ = 86 g/cm^2
    - $\lambda_{Fe,CsI}$ = 58 g/cm^2
  - GCR at 45 deg traverses ~100 g/cm^2 of CsI
    - ~30% of CNO group and
      ~20% of Fe survive without interacting.
- **How many per day in each CsI bar?**
  - **~1100 non-interacting CNO.**
  - **~70 non-interacting Fe.**

- **Scintillation efficiency**
- Light output of CsI(Tl) is not strictly proportional to ΔE for heavy ions.
  - dL/dE, the light output per unit energy loss, decreases slowly with increasing dE/dx for heavy ions, but is constant for EM showers.
  - dL/dE is fcn of dE/dx, rather than charge of the beam.
  - Magnitude (in NaI!!):
    - ~0.9 near minimum ionizing.
    - ~0.3 near end of range.
- Need to measure in heavy ion beam!



Appendix 1: Calibration with Cosmic Rays

- **Calibration Uncertainty**
- Need to bin GCRs by estimated ΔE.
  This is uncertain for following reasons:
  - Uncertainty in initial energy.
    - ΔdE/dx ~ 10% over 2 - 6 GeV/n.
  - Landau fluctuations.
    - σ_L < 5% for CNO near 5 GeV/n.
    - σ_L < 5% for Fe near 5 GeV/n
  - Unidentified nuclear interactions.
    - p-stripping from C is hard to miss.
    - p-stripping from Fe.
      - ΔE < 10%.
  - Uncertainty in dL/dE.
    - Guess < few %.
- Adding in quadrature gives rms < 20%.
- With ~1000 CNO per bar per day, statistical **precision of ~1% per day is achievable**.